

3-5 November 2004 Annapolis, Maryland

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Introduction

#### Welcome

Solar physicists are currently confronted by a rich set of imaging data from a variety of ground- and space-based observatories, and there is a lot of interest in the community in making a coordinated approach to the problem of maximizing the scientific return of this data.

This workshop aims to provide (1) an overview of the current state of the art of image processing in solar physics and (2) exposure to modern image processing approaches that may be unfamiliar to solar physicists. We intend to provide a multi-disciplinary forum for the cross-pollination of the solar physics and image processing communities so that we may maximize the science returns from existing and future datasets. SIPWork II will follow on the success of the Solar Image Recognition Workshop held in the Royal Observatory of Belgium in October 2003. The application image processing methods to existing data - such as RHESSI, SOHO, TRACE, BBSO, and the VTT - and to the large volume and variety of data from upcoming missions - such as SDO and STEREO - will be discussed.

This Workshop is supported by NASA's Sun-Earth Connection Division.

#### Organisers

P.T. Gallagher (Chair)
J. Ireland (LOC, SOC)
R.T.J. McAteer (LOC, SOC)
C.A. Young (LOC, SOC)
A. Rosas (LOC)
D. Berghmans (SOC)
R. Bentley (SOC)
V.V. Zharkova (SOC)

**Programme** 

**Timetable** 

| Wednesday 3rd November |  |  |  |
|------------------------|--|--|--|
| 9:00- 9:30             | Welcome  |  |  |
|                        | Peter Gallagher  |  |  |
| Session 1              | General Introductory Session   |  |  |
| Chair:                 | David Berghmans  |  |  |
| 9:30-10:10             | C. Alex Young (L-3 Communications GSI/NASA GSFC)   |  |  |
|                        | Overview of Image Processing in Solar Physics (invited)                                    |  |  |
| 10:10-10:30            | David Berghmans (Royal Observatory of Belgium)   |  |  |
|                        | SWAP & LYRA onboard PROBA-2, Solar event recognition on a technology demonstration mission |  |  |
| 10:30-11:00            | Coffee and Posters   |  |  |
| 10.30-11.00            | Correct and 1 osters   |  |  |
| 11:00-11:20            | Brian Welsch (University of California, Berkeley)  |  |  |
|                        | Combining Local Correlation Tracking with the Magnetic Induction Equation                  |  |  |
| 11:20-11:40            | Aleksandra Andic (University of Göttingen)   |  |  |
|                        | Short period oscilations in the solar atmosphere   |  |  |
| 11:40-12:00            | Dario Del Moro (University of Rome 'Tor Vergata')  |  |  |
|                        | Solar Photospheric and Chromospheric Patterns analyzed via Information Entropy             |  |  |
| 12:00-12:20            | Athanassis Katsiyannis (Royal Observatory of Belgium)                                      |  |  |
|                        | Automated detection of oscillations on SECIS observations using wavelet analysis           |  |  |
| 12:20-12:40            | <b>Bogdan Nicula</b> (Royal Observatory of Belgium)  |  |  |
|                        | The Solar Weather Browser  |  |  |
| 12:40- 1:00            | <b>Tom Bridgman</b> (Global Science & Technology, Inc./NASA GSFC)                          |  |  |
|                        | Trends in Solar Data Visualization for Research and Education/Public Outreach              |  |  |
|                        | Lunch  |  |  |

#### Wednesday 3rd November Session 2 **Multi-scale Methods** Chair: Jack Ireland 2:30-3:10 Guillermo Stenborg (Catholic University of America/NASA GSFC) A Review of Wavelet Techniques in Solar Image Processing (invited) 3:10-3:30 Valentyna Abramenko (Big Bear Solar Observatory) Multifractal analysis of solar images 3:30-3:50 **Veronique Delouille** (Royal Observatory of Belgium) Wavelet spectrum analysis of EIT-SoHO observations 4:00-4:30 **Coffee and Posters** 4:30-4:50 Manolis Georgoulis (Johns Hopkins Applied Physics Laboratory) Manifestations and Diagnostics of Turbulence in the Solar Atmosphere 4:50-5:10 **K. Revathy** (Kerala University) Fractal based fuzzy technique for detection of active regions from solar images 5:10-5:30 Peter W. Schuck (Naval Research Laboratory) The Accurate and Precise Estimation of Velocity and Associated Uncertainties of Flows in Solar Image Sequences 5:30-5:50 Scott McIntosh (Southwest Research Institute) Shape up or Shapelets

#### **Thursday 4th November** Session 3 **Image Restoration and Enhancement** Markus Aschwanden Chair: 9:40- 9:40 Carsten Denker (New Jersey Institute of Technology) Image Reconstruction in Solar Physics (invited) 9:40-10:00 Katarzyna Mikurda (Kiepenheuer Institut Für Sonnenphysik) Automated recognition and tracing of G-band bright points 10:00-10:20 Michiel van Noort (University of Oslo) Multi-Object Phase Diversity Solar Image Reconstruction 10:30-11:00 **Coffee and Posters** 11:00-11:20 Mats Lofdahl (Royal Swedish Academy of Sciences) Image quality effects from wavelength dependent pupil apodisation in narrow-band filters 11:20-11:40 Craig DeForest (Southwest Research Institute) Truth, Distortions, and Lies: An Image Resampling Primer 11:40-12:00 Stanislava Simberova (Czech Academy of Sciences) Multichannel Blind Deconvolution as a Tool for Solar Image Restoration 12:00-12:20 Serena Criscuoli (High Altitude Observatory) First results of Phase Diversity technique at THEMIS 12:20-12:40 Richard Schwartz (SSAI/NASA GSFC) **RHESSI** Imaging 12:40- 1:00 **Stephen White** (University of Maryland) Imaging with the Frequency Agile Solar Radiotelescope

Lunch

#### **Thursday 4th November** Session 4 **Breakout Session** Chair: Dominic Zarro 2:30-4:00 Several data sets will be supplied by the SOC for attendees to try out their favourite image processing techniques on. This is an informal session where attendees will be encouraged to work in small groups on specific problems in solar image processing. Group 1 Markus Aschwanden Coronal data - TRACE/EIT Group 2 Guillermo Stenborg Coronagraph data - LASCO/MLSO/etc. Group 3 **Craig DeForest** Magnetic field - MDI/BBSO/etc. Group 4 Frank Hill Ground based - H-alpha/G-band/etc. 4:00-4:30 **Coffee and Posters** 4:30-6:00 Breakout Session (continued) **8pm:** Banquet in Hotel

| Friday 5th November |  |  |
|---------------------|--|--|
| Session 4           | Reports on the Breakout Sessions   |  |
| Chair:              | Dominic Zarro  |  |
| 9:00- 9:50          | Informal presentations and discussion of breakout session findings.                                  |  |
| Session 5           | Feature Recognition and Classification   |  |
| Chair:              | David Rust   |  |
| 9:50-10:30          | Frank Shih (New Jersey Institute of Technology)  |  |
|                     | Overview of Machine Learning in Solar Physics (invited)  |  |
| 10:30-11:00         | Coffee and Posters   |  |
| 11:00-11:20         | Valentina Zharkova (University of Bradford)  |  |
|                     | Solar Feature Catalogues in EGSO   |  |
| 11:20-11:40         | Markus Aschwanden (Lockheed Martin)  |  |
|                     | Feature Recognition Algorithms applied to solar EUV im-  |  |
| 11 40 12 00         | ages   |  |
| 11:40–12:00         | Eva Robbrecht (Royal Observatory of Belgium)   |  |
|                     | Entering the era of automated CME recognition: a review of existing tools                            |  |
| 12:00-12:20         | <b>Pietro Bernasconi</b> (Johns Hopkins Univ./Applied Physics Lab.)                                  |  |
|                     | Results from an Advanced Automated Filament Detection and Characterization Code                      |  |
| 12:20-12:40         | Nicolas Fuller (LESIA/Observatoire de Paris)   |  |
|                     | Automatic detection of prominences using Meudon spectroheliograms                                    |  |
| 12:40- 1:00         | Stanley Ipson (University of Bradford)   |  |
|                     | Automatic comparison of magnetic field inversion with filament data from the Solar Feature Catalogue |  |

Lunch

|           | Friday 5th November  |
|-----------|--|
| 2:30-2:50 | Sergei Zharkov (University of Bradford)  |
|           | Solar Cycle Statistics extracted from the Sunspot Feature Catalogue  |
| 2:50-3:10 | Trung Nguyen (University of Bath)  |
|           | On Learning of Sunspot Classification  |
| 3:10-3:30 | Ali Benkhalil (University of Bradford)   |
|           | Using the Solar Feature Catalogue for Tracking Solar Active Regions and Search for Classification parameters |
| 3:30-3:50 | Elena Podladchikova (Royal Observatory of Belgium)   |
|           | EIT wave and dimmings recognition algoritm for STEREO/SECCHI data  |

| Session 6 | Future Prospects for Solar Imaging           |
|-----------|--|
| Chair:    | Bob Bentley                                  |
| 4:30-5:10 | Frank Hill (National Solar Observatory)      |
|           | The Future of Solar Imaging (invited)        |
| 5:10-6:00 | Closing group discussion led by Bob Bentley. |

**Coffee and Posters** 

4:00-4:30

## Session 1 General Introductory Session

Chair: David Berghmans

#### **Overview of Image Processing in Solar Physics**

Young, C. Alex

#### **Abstract**

Invited Review

The purpose of this workshop is to expose the solar physics community to the broad range of image processing tools available. We review many of these tools and then look at how some of these tools and techniques have been applied to solar physics data.

### SWAP and LYRA onboard PROBA-2, Solar event recognition on a technology demonstration mission.

BERGHMANS, D., HOCHEDEZ, J.F., NICULA, B., DELOUILLE, V.

#### **Abstract**

PROBA-2 is a small technology demonstration mission of the European Space Agency, planned for launch mid 2006. The scientific payload will consists of the EUV imager SWAP (Sun Watcher using APS and Image Processing) and the UV radiometer LYRA (Large Yield Radiometer). Both instruments are proposed as space weather monitors and contain a variety of hardware and software innovations.

The onboard software will be used for advanced image compression, giving telemetry priority to the most interesting data first, and possible for CME tracking i.e. off-pointing the spacecraft to keep the CME in the FOV during the ejection. On the ground, the processing pipeline will apply automated event recognition on the data stream and trigger automatically space weather event warnings.

We will review the current status of the instrument & spacecraft design and our development plans for the onboard/ground software.

## **ILCT: Combining Local Correlation Tracking with the Magnetic Induction Equation**

WELSCH, B.T., FISHER, G.H., ABBETT, W.P., REGNIER, S.

#### **Abstract**

In order to use sequences of magnetogram data as input to MHD simulations of the solar atmosphere, one must ensure that the data is consistent with the MHD induction equation. We describe inductive local correlation tracking, or ILCT, which can determine a flow field consistent with the ideal MHD induction equation. The flow fields are thus suitable for incorporation into the photospheric boundary of an MHD simulation of the solar atmosphere.

#### Short period oscilations in the solar atmosphere

ANDIC, A., KNEER, F.

#### **Abstract**

Short period waves in the range of 50 - 110 s are investigated with lines FeI 534.29 nm and FeI 534.54 nm. Observations from several data sets are analysed using wavelet transform. For the determination of the heights in the atmosphere where the observed velocity fluctuations are formed we calculated velocity response function assuming LTE. The analysis gives indications of acoustic waves and magneto-acoustic waves at different heights. The two types of waves are located at different positions with respect to the granulation pattern and show different behaviour. We present, also, evidence for waves traveling through the atmosphere.

## Solar Photospheric and Chromospheric Patterns analyzed via Information Entropy

**DEL MORO, D.**, BERRILLI, F., GIORDANO, S., FLORIO, A., CONSOLINI, G., PIETROPAOLO, E.

#### **Abstract**

The existence and the nature of relevant scales and the evolution of solar photospheric and chromospheric patterns are still open topics. In this paper we present a procedure to extract cell boundaries both from photospheric granulation and Chromospheric network based on an iterative development of the Medial Axis Transform. Successively, a quantitative measure of characteristic scale size is performed on the segmented pattern via the normalized information entropy.

### Automated detection of oscillations on SECIS observations using wavelet analysis

KATSIYANNIS, A.C.

#### **Abstract**

8000 images of the Solar corona were captured during the June 2001 total Solar eclipse. New software for the alignment of the images and an automated technique for detecting intensity oscillations using multi scale wavelet analysis were developed. Large areas of the images covered by the Moon and the upper corona were scanned for oscillations and the statistical properties of the atmospheric effects were determined. Some preliminary results of corona loop oscillations with 8sec periodicity are presented.

#### The Solar Weather Browser

NICULA, B., BERGHMANS, D.

#### **Abstract**

The Solar Weather Browser (SWB) is a client/server tool developed by the Royal Observatory of Belgium for easy visualisation of solar images in combination with any context information that can be overlaid on the images.

The server side preprocesses a wide variety of solar images and context data into a highly compressed format that is accessed by the client side on the user machine. The compression technique developed for SWAP (Sun Watcher using APS detectors and image Processing) is used for achieving its scalability goals.

On the client side the user can interactively combine background images (eg EIT) with overlays (eg sunspot or filament locations). This allows an enormous number of image/overlays combinations (currently on the order of 1000) which would not be feasible in a non-interactive set-up. We believe that this feature is particularly useful for the presentation of the results of automated solar image recognition/processing chains.

Given its highly optimised image compression and transmission, the SWB is also potentially useful in the context of distributed solar image archives where it could play the role of quicklook previewer.

The SWB is an open-source development, readily downloadable for all major platforms.

We will present the current state of the SWB and invite contributions for further development.

## Trends in Solar Data Visualization for Research and Education/Public Outreach

BRIDGMAN, W.T.

#### **Abstract**

Ten years ago, making movies of science results might have involved taking pictures of a computer screen and having a video technician transfer and composite them to video tape. Now, thanks to imaging standards and powerful hardware at a reason able cost, this capability is available on the scientist's desktop computer. What changes and new capabilities are on the horizon? What will we want to do with the data of tomorrow?

Session 2
Multi-scale Methods

Chair: Jack Ireland

#### A Review of Wavelet Techniques in Solar Image Processing

STENBORG, G.

#### Abstract

Invited Review

No Abstract Provided

#### Multifractal analysis of solar images

ABRAMENKO, V.

#### **Abstract**

As the solar observational technique improves, the fine small-scale structure of features observed on the solar surface becomes more pronounced. Complex filigree structures of solar granulation, sunspots, photospheric magnetic and velocity fields can not be represented adequately by a single parameter (e.g., filling factor, fractal dimension, or power law index, etc.). Methods which incorporate parameters as a function of scale (multi-scale methods) to describe the complexity of a field under study, should be involved. The multifractal analysis offers such a possibility through the calculation of a spectrum of (multi-)fractal dimensions. There exist several ways to obtain such (multi-)fractal spectrum. We propose (Abramenko et al. 2002, 2003) to calculate scaling of the structure functions of a 2D field. The method gives us information on multifractal properties of the field itself and of its energy dissipation. When applied to the line-of-site magnetic field of different active regions, our method shows that the degree of multifractality correlates with the flaring activity of an active region. This inference may contribute to the problems of energy built-up and triggering of a solar flare.

## Wavelet spectrum analysis of EIT-SoHO observations

**DELOUILLE, V.**, HOCHEDEZ, J.F., PATOUL DE, J., JACQUES, L., ANTOINE, J-P.

#### **Abstract**

The Extreme ultraviolet Imaging Telescope (EIT) of SoHO provides a high-resolution and large sampling of the solar corona in time, space and brightness. To extract the wealth of its physics, it is useful to consider a multiscale approach. The wavelet spectrum is used to analyse the distribution of scales in our data set, and to derive an automatic way for separating active regions from Quiet Sun. The global behaviour of the small scales offers a powerful way to monitor coronal activity, which could improve forecasting of the Solar activity with potential to Space Weather predictions.

## Manifestations and Diagnostics of Turbulence in the Solar Atmosphere

GEORGOULIS, M.

#### **Abstract**

It is believed that the magnetized solar atmosphere is fully turbulent. Magnetohydrodynamic turbulence refers to a superposition of three types of magnetic structures with different ranges of length scales: (1) Large-scale structures carrying free magnetic energy, (2) an inertial, power-law, range of decreasing length scales and free energy fragmentation, and (3) sufficiently small-scale structures that dissipate magnetic energy. We discuss how a such process manifests itself in the solar atmosphere via temporal intermittency in the energy release process and spatial (possibly critical) self-organization which translates to self-similarity and fractal structures. Fractal and multi-fractal measures of intermittency are briefly discussed, with the emphasis given on actual examples of dissipative fractal structures. A central question is whether the study of the above fractal patterns can contribute to the forecasting of flares / coronal mass ejections or to the solution of the coronal heating problem. The answer is unclear but it is conceivable that image processing and/or filtering techniques may help reveal possible critical thresholds in the flare-triggering process and thus may quantify the above problems for the first time.

## Fractal based fuzzy technique for detection of active regions from solar images

REVATHY, K.

#### **Abstract**

The most common and easiest way to extract regions of interest from an image is through segmentation. Segmentation techniques vary from the conventional edge detection mechanism to fuzzy c-means clustering. In this study, we have applied local fractal operator technique to images, followed by different segmentation procedures. The fuzzy based approach to segmentation problem is discussed and the different segmentation algorithms are compared. These techniques have been applied on solar images and fuzzy based approach is used to extract active regions elegantly.

#### The Accurate and Precise Estimation of Velocity and Associated Uncertainties of Flows in Solar Image Sequences

SCHUCK, P.W.

#### **Abstract**

Modern controversies in solar physics demand a statistically robust technique for determining the "optical flow" perpendicular to the line of sight from a sequence of solar images. Local Correlation Tracking (LCT) is the de-facto standard for estimating optical flow in solar image sequences. However, this technique has many documented limitations. Perhaps the greatest limitations of LCT are the absence of demonstrated accuracy, precision and a quantifiable local uncertainty associated with the velocities derived from this technique, and the introduction of artificial scales. I will present a new technique that represents a generalization of established wavelet interferometric techniques to the multi-point data represented by solar image sequences.

The new technique determines the velocity field based on a statistically robust estimate of the local group velocity of fluctuations. The analysis is localized in space through a wavevector k(x,w,t) determined by spatio-temporal analysis of each individual pixel over the entire image sequence. The temporal spectral analysis is localized in time using the time-frequency localization properties of the Morlet wavelet transform which provides an optimal balance of temporal and frequency localization simultaneously. The velocity field is computed from the mean of the phase velocity w/k averaged over all frequencies. The variance provides a statistically robust uncertainty for this estimate. The magnitude of the variance directly indicates when the local spectral components are moving with the same velocity, i.e., the group velocity. The technique identifies when the concept of a local velocity is correct, and can be extended to analyze turbulent situations where it is not correct. This tool will be applicable to estimating differential rotation, surface flows of meso- and supergranuls, helicity injection, the convective structure of an emerging flux region, systems of sunspots and pores, and many other solar phenomena.

### **Shape-up or Shapelets**

McIntosh, S.W.

#### Abstract

No Abstract Provided.

## Session 3 Image Restoration and Enhancement

Chair: Markus Aschwanden

### **Image Reconstruction in Solar Physics**

DENKER, C.

#### Abstract

Invited Review

No Abstract provided

## Automated recognition and tracing of G-band bright points

MIKURDA, K.

#### **Abstract**

G-band bright points (GBPs) are pointlike brightenings seen in the solar photosphere while observing at G-band (430 nm). Their main characteristics are: small sizes (0.1"-0.7"), high contrast to photosphere, lifetimes similar to those of granules. Several authors have found counterparts of GBPs in magnetograms (Berger & Title, 2001, Muller et al., 2000), however it seems that not all of GBPs would have them (Berger & Title, 2000, Langhans et al., 2002). The dynamics of G-band bright points have been studied by many authors (for example Berger & Title, 1996, Muller et al., 1994) and the velocities of 0.5-5 km/s across the photosphere have been found.

The problem of automated detection and tracking GBPs was pointed by many authors (see for example: Berger et al., 1995, Ballegooijen et al.,1998). GPBs have high contrast to the intergranular lines, but are not neccessary brighter than granules, so simple thresholding would not distinguish them. Automated detection of GBPs is extremely important, while using cameras with large field of view, because their number on a single frame can be quite large (more than 500). Todays observational techniques (adaptive optics, but also observations from space) and postprocessing techniques provide long, undisturbed time series, so is almost impossible to detect and trace small structures only visually.

In my presentation I will discuss the methodes of G-band bright points identification used by us (blob-finding algorithm, wavelet- and Fourier filtering- based methods, gradient investigation), as well as challenges of G-band bright points tracing.

#### **Multi-Object Phase Diversity Solar Image Reconstruction**

VAN NOORT, M.

#### **Abstract**

We developed a new, faster version of the phase diversity image reconstruction code written by M. Lo"fdahl. Because of the increase in speed over the old code of a factor 30, a larger number of images can be combined, resulting in improved stability and ability to handle worse seeing conditions than was possible with the old code.

Recent enhancements have made it possible to combine images taken at different wavelengths, further increasing stability and making exact alignment between them possible. This feature has been used to create magnetograms and Dopplergrams with a very low granulation noise.

## Truth, Distortions, and Lies: An Image Resampling Primer

DEFOREST, C.E.

#### **Abstract**

Image resampling is generally the first step performed on calibrated, despiked image data for analysis. It is used to co-align data from disparate instruments, to compensate for perspective effects, to remove solar rotation, and to undo instrumental distortions. Unfortunately, the solar community is not, as a whole, well versed in resampling techniques. The result is that many data are analyzed less well than they could be in the appropriate coordinate system, and data that are resampled are frequently damaged in the process. I will describe a more correct technique for resampling image data, and demonstrate software that I have developed to manipulate and apply coordinate transformations easily to scientific image data.

### Multichannel Blind Deconvolution as a Tool for Solar Image Restoration.

SIMBEROVA, S.

#### **Abstract**

Two restoration methods based on multichannel blind deconvolution (MBD) are presented. The methods assume that for every undegraded unobservable image several degraded observed images are available. It is better conditioned than classical single channel approach. The first method represents a generalization of iterative deconvolution scheme introduced for single images. The second MBD algorithm is based on so-called subspace technique. The subspace method is not iterative and this possibly implies an implementation that can be computationally more efficient. Both methods are presented in applications to artificial image data (computer generated multichannel degraded data) with known ideal image to get a comparison with restored one. The performance in a real situation on the solar photosphere images is shown. For experiments the ground-based observations of the short-exposure images have been used (Ondrejov Observatory, white light).

## First results of Phase Diversity technique at THEMIS

CRISCUOLI, S.

#### **Abstract**

Phase Diversity techniques are robust post processing tools for image enhancment and correction of telescopic and atmospheric aberrations. We present the first results obtained applying Partitioned Phase Diverse Speckle technique in THEMIS. We also present an image quality estimator based on power spectrum content.

#### **RHESSI Imaging Talk**

SCHWARTZ, R.A.

#### **Abstract**

For many reasons the current implementation of MEM in the RHESSI software is problematic. This presentation shows my progress in revising the algorithm. The current approach uses a pixel basis but this will discuss alternate bases that work more naturally with MEM.

## Imaging with the Frequency Agile Solar Radiotelescope

WHITE, S.

#### **Abstract**

In addition to the general problem of producing images from an interferometric array, FASR presents a range of deconvolution and related technical problems. This talk will discuss these issues, their role they play in the design of FASR, and the plans to address them.

## SIPWorkII Solar Image Processing Workshop

Session 4
Breakout Session

Chair: Dominic Zarro

#### **Breakout Session**

#### ZARRO, D.

#### **Abstract**

Several data sets will be supplied by the SOC for attendees to try out their favourite image processing techniques on. This is an informal session where attendees will be encouraged to work in small groups on specific problems in solar image processing. This session runs from Wednesday 4th November 2:30-4:00pm, 4:30-6:00pm, with informal presentations of the session findings on Friday 5th November 9:00-9:50am.

For data and suggested topics of discussion, see http://www.solarmonitor.org/~ptg/sipworkii/data/

- Group 1: Markus Aschwanden Coronal data TRACE/EIT
- Group 2: Guillermo Stenborg Coronagraph data LASCO/MLSO/etc.
- Group 3: Craig DeForest Magnetic field MDI/BBSO/etc.
- Group 4: Frank Hill Ground based H-alpha/G-band/etc.

## SIPWorkII Solar Image Processing Workshop

## Session 5 Feature Recognition and Classification

Chair: David Rust

## Overview of Machine Learning in Solar Physics Shih, F.

#### **Abstract**

#### Invited Review

We present an overview of machine learning techniques including statistical and syntactic pattern recognition, fuzzy logic, neural networks, and support vector machines. The focus of the automatic solar feature detection is on the development of efficient feature-based classifiers. We have experimented the different classifiers for solar flare detection on the solar H-a (Hydrogen-Alpha) images obtained from the Big Bear Solar Observatory in California. The preprocessing step is to obtain the nine principal features of the solar flares for the classifiers. Experimental results show that by using SVM, we can obtain the best classification rate of the solar flares. We believe our work will lead to real-time solar flare detection using advanced pattern recognition techniques.

#### **Solar Feature Catalogues in EGSO**

**ZHARKOVA, V.V.**, IPSON, S.S., ABOUDARHAM, J., ZHARKOV, S.I., BENKHALIL, A. K. AND FULLER, N.

#### Abstract

General presentation of the existing searcheable catalogues of sunspots, active regions and filaments, their parameters, structure and feature verification.

## Feature Recognition Algorithms applied to solar EUV images

ASCHWANDEN, M.J.

#### **Abstract**

EUV images show the solar corona in a typical temperature range of T > 1MK, which encompasses the most common coronal structures: loops, filaments, and other magnetic structures in active regions, the quiet Sun, and coronal holes. Quantitative analysis of 3D and time-dependent structures increasingly demands automated algorithms to localize, track, and monitor the evolution of such coronal structures. We present numerical tools that "fingerprint" linear curved features, i.e., loops and filaments that can be represented by a 1D parameterization x(s), y(s), z(s), with (s) being a length coordinate. We demonstrate the performance of finger-printing algorithms without additional assumptions, which generally suffer from incomplete and segmented tracing. We demonstrate also modified tracing algorithms which connect most fitting segments to more complete structures. Then we demonstrate a number of algorithms that make use of additional a priori constraints, such as (1) the heliographic position, (2) guidance by magnetic field extrapolations, (3) force-free fields, (4) maximization of curvature radii, and (5) conservation of velocity and/or acceleration parameters in time-dependent image sequences. We discuss the efficiency and applicability of these algorithms to the analysis of SoHO/EIT, TRACE, and STEREO/SECCHI data.

## Entering the era of automated CME recognition: a review of existing tools

ROBBRECHT, E., BERGHMANS, D.

#### **Abstract**

Over the past 8 years, coronal mass ejections (CMEs) have been detected routinely by visually checking each image from the Large Angle Spectrometric Coronagraph (LASCO) onboard SOHO. Event catalogs have been assembled continuously and are made publicly available. These catalogs are used as a reference and form a valuable resource for further statistical analysis on the nature of CMEs. However, the space weather community needs near-real-time alerts of (partial) halo CMEs. Although in typical cases such halo CMEs take a few days (3-4) to travel to the Earth, their timely detection is important as CPU-time intensive 3D MHD simulations are required to estimate their geo-effectiveness. This implies that CME halo alerts should be issued 24 hours per day. With the advent of new coronagraphs onboard STEREO this would become a big strain on manpower. For these and other reasons new software is being developed to automatically recognize CMEs in coronagraphic images. A the beginning of this new era of automatically tracking CMEs we give a review of state-of-the-art tools (existing or in development) and discuss their differences in image preprocessing, feature tracking technique, output characteristics, output format, strong and weak points, time-scales, success rates, etc. As a base for output-comparison we use the SOHO LASCO CME catalog.

#### Results from an Advanced Automated Filament Detection and Characterization Code

BERNASCONI, P.N., RUST, D.M., HAKIM, D.

#### **Abstract**

We report on the further development and enhancements of a code for the detection and characterization of solar filaments in full-disk H-alpha images. We first presented the code at the Solar Image Processing Workshop I in Brussels (2003). The advanced code is more robust and reliable in identifying and characterizing the filament chirality and is now capable of tracking the day-by-day evolution of filaments while they travel across the visible disk. The code was tested by analyzing daily H-alpha images taken at the Big Bear Solar Observatory during a period of four years (from mid 2000 until mid 2004). It identified and established the chirality of more than 5000 filaments without human intervention. We compared the results with the filament list manually compiled by Pevtsov et al. over the same period of time. The computer list matches the Pevtsov et al. list fairly well. The code results confirm the hemispherical chirality rule: dextral filaments predominate in the north and sinistral ones predominate in the south. The main difference between the two lists is that the code finds significantly more filaments without an identifiable chirality. This may be due to a tendency of human operators to be biased, thereby assigning a chirality in less clear cases, while the code is totally unbiased. We also have found evidence that filaments with definite chirality tend to be larger and last longer than the ones without a clear chirality signature. We will describe the major improvement of the code and present and discuss the tests results.

## Automatic detection of prominences using Meudon spectroheliograms

FULLER, N., ABOUDARHAM, J.

#### **Abstract**

In the frame of the EGSO project, we developed an automatic detection of solar prominences. This detection is based on Meudon Ca II K3 spectroheliograms which are freely available in BASS 2000 Solar Suvey database in Meudon. This work is complementary to the previously developed detection of filaments.

## Automatic comparison of magnetic field inversion with filament data from the Solar Feature Catalogue

IPSON, S.S., ZHARKOVA, V.V., ZHARKOV, S., BENKHALIL, A.K., ABOUDARHAM, J. AND FULLER, N.

#### Abstract

This paper outlines the methodology and algorithms used to compare filament data automatically extracted from H alpha images from the Meudon Observatory in France and stored in the EGSO Solar Feature Catalogue with magnetic inversion lines calculated for corresponding synchronised SOHO/MDI magnetograms. Some statistical results obtained for angular alignment, displacement and field magnitudes are presented and discussed.

#### Solar Cycle Statistics extracted from the Sunspot Feature Catalogue

ZHARKOV, S.I., ZHARKOVA, V.V., IPSON S.S.

#### **Abstract**

The EGSO sunspot catalogue built by means of automated detection from SOHO / MDI continuum data, 1996-2004, offers a comprehensive list of parameters for analysis. We look at extracted statistics as Solar Activity indicators and examine the North-South asymmetry.

#### On Learning of Sunspot Classification

NGUYEN, T.

#### **Abstract**

This paper describes automatic sunspot recognition and classification from satellite images. Some experimental results on learning sunspot classification using data mining techniques are presented. The classification scheme used was the seven-class Modified Zurich scheme. Daily images of the solar disk were taken from the NASA SOHO satellite's MDI instrument and sunspots extracted using image processing techniques. Two data mining tools, WEKA and RSES, were used for learning sunspot classification. In the training dataset sunspots were manually classified by comparing extracted sunspots with corresponding active region maps.

#### Using the Solar Feature Catalogue for Tracking Solar Active Regions and Search for Classification parameters

BENKHALIL, A.K., ZHARKOVA, V.V., ZHARKOV, S.I., IPSON, S.S.

#### **Abstract**

This paper presents the application of Solar Feature Catalogue (SFC) created with an automated technique for active region detection from SOHO / MDI, SOHO / EIT and H $\alpha$  images from Meudon. Based on a comparison of the active region parameters selected from the SFC with the magnetic field configuration and strength we try to select the key parameters defining a region activity in flare production that can be used for a preliminary active region classification.

### EIT wave and dimmings recognition algoritm for STEREO/SECCHI data

PODLADCHIKOVA, E., BERGHMANS, D., ZHUKOV, A.

#### **Abstract**

Automatic recognition of coronal dimmings and EIT waves is not obvious because of diversity and transient character of these objects. We develop numerical algorithms based on combination of several methods such as evaluation of higher order moments, SVD and adaptive Kalman filering. Our goal is to detect automatically EIT waves and dimmings in the STEREO/SECCHI mission. We test them on the EIT/SOHO data catalogs.

On current stage of work we can unambiguously detect dimmings and EIT waves having short life time in the presence of one big active region on the Sun. We present preliminary results on the extraction of these events from the data, and the determination of such parameters as life time, depth, surface and volume of dimmings for future catalog. For EIT waves we extract eruption center, the front of EIT wave and we define its propagation velocity. We will shortly discuss some new detected features of EIT waves and possible MHD model explaining them.

# SIPWorkII Solar Image Processing Workshop

Session 6
Future Prospects for Solar
Imaging

Chair: Bob Bentley

#### The Future of Solar Imaging

HILL, F.

#### **Abstract**

#### Invited Review

The continued growth of computing and communication technologies is revolutionizing our ability to analyze solar data. The resources now available on the desk of the average researcher exceed national supercomputing resources of the mid 1980s. In this talk I will review the latest developments and likely future trends that will impact the life of the solar physicist. In particular, the advent of grid computing, Internet 2, inexpensive disk arrays, high-speed prcoessors and virtual observatories will be discussed.

#### **Closing group discussion**

BENTLEY, R.

#### Abstract

Led by R. Bentley.

# SIPWorkII Solar Image Processing Workshop

**Poster Session** 



## **Integrating the EGSO Feature Recognition Catalogue into SolarSoft**

Bentley, R.D., Zharkova, V.V., Abourdarham, J.

#### Abstract

There are now more than 4 years of feature data for sunspots, filaments and active region page in the ESGO Solar Feature Catalogue. Techniques have been developed that allow these to be accessed directly from within a SolarSoft session so that the user can easily other plot feature and event data on an image of their choice. This will be demonstarted together with other capabilities of EGSO.

## A parallel implementation of the CLEAN algorithm for the BDA

**BETHI, N.K.**, FARIA, C., PRETO, A.J., STEPHANY, S., ROSA, R.R., SYCH, R., SAWANT, H.S.

#### **Abstract**

The Brazilian Decimetric Array (BDA) is a radio interferometer consisting of 38 antennas, with 4 or 5 meter diameter for solar/non solar observations. The Prototype Brazilian Decimetric Array of 5 elements with base lines up to 32 meters is in regular operation at S. J. dos Campos presently. These 5 antennas are being shifted to Cahoeira Paulista (CP) where baselines will be increased up to a distances of 210 meter. This new configuration will permit one dimensional solar radio images of the sun and its activity in snap shot mode.

The BDA software image processing system uses the CLEAN algorithm for image deconvolution. The high input data rate suggests a parallel implementation in order to achieve near real-time visualization. The current work presents a new parallel version of the Hogbom CLEAN algorithm, using the MPI (Message Passing Interface) communication library.

The software is being implemented on a cluster located at Computing and Applied Mathematics Laboratory (LAC/INPE). This machine is composed of 17 nodes, with 1.67 GHz AMD processors, connected by a Fast Ethernet switch.

This version is being tested with two-dimensional dirty images obtained from Siberian Solar Radio telescope at 5.6 GHz. Hence the results obtained using SSRT data will be presented.

#### **BLIP - BLinker Identification Procedure**

BEWSHER, D.

#### **Abstract**

BLIP (BLinker Identification Procedure) is an automated method of identifying blinkers, small scale intensity enhancements observed in the transition region of the Sun's atmosphere. We will present details of the identification algorithm and examples of blinkers identified using the algorithm.

#### Wavelet Phase Coherence Analysis: Application to a Quiet-Sun Magnetic Element

**BLOOMFIELD, D.S.**, MCATEER, R.T.J., LITES, P.G., JUDGE, P.G., MATHIOUDAKIS, M., KEENAN, F.P.

#### **Abstract**

A new application of wavelet analysis is presented, which utilises the inherent phase information residing within the complex Morlet transform. The technique is applied to a weak solar magnetic network region, and the temporal variation of phase difference between TRACE 1700 A and SoHO/SUMER C II 1037 A intensities is shown. We present, for the first time in an astrophysical setting, the application of wavelet phase coherence, including a comparison between two methods of testing real wavelet phase coherence against that of noise. The example highlights the advantage of wavelet analysis over more classical techniques such as Fourier analysis, and the effectiveness of the former to identify wavepackets of similar frequencies but with differing phase relations is emphasized. Using co-temporal, ground-based Advanced Stokes Polarimeter measurements, changes in the observed phase differences are shown to result from alterations in the magnetic topology.



#### Data Rescue Solar Image Scanning Project Samples

COFFEY, H.

#### **Abstract**

The National Oceanic and Atmospheric Administration (NOAA) Climate Database Modernization Program (CDMP) project is funding the scanning of many solar images to digital format to make them available to the community via the National Geophysical Data Center Website

(http://www.ngdc.noaa.gov). The daily images include sunspot drawings 1924-1948 by H.H. Clayton, Canton, Massachusetts; sunspot drawings 1948-present from Boulder, Sacramento Peak, Ramey and Holloman Observatories; U.S. Naval Observatory white light photos 1946-1964; McMath-Hulbert Calcium K and Halpha photos 1948-1978; McMath-Hulbert daily calcium drawings 1942-1987; as well as Fraunhofer maps (1956-1973) and Wendelstein (1950s-1980s) drawings of a multitude of solar phenomena on one daily map. The scanned daily images document many phases of solar activity, from decadal variation to rotation variation to daily changes. An overview of the project and sample images will be given. Input and advice from the community is requested.

#### Be Shared or Be Nowhere

FREELAND, S.

#### **Abstract**

Solicitation of software contributions from SIPWorkII participants who are interested in sharing tax payer financed software efforts with the LWS, VxO, Space Weather, Lunar and Mars Base inhabitants, Tom Ridge, and other interested communities v ia SolarSoft.

P.S. Ask me about SolarSoft Platinum 3.0!! Innovative solutions for YOUR special solar physics, space weather, and solar system space travel requirements!!!



## Motion Analysis Algorithm applied to EIT Sequences

GISSOT S., HOCHEDEZ, J.F., JACQUES, L., ANTOINE, J.-P.

#### **Abstract**

The EIT (Extreme ultraviolet Imaging Telescope) instrument onboard the SoHO spacecraft provides sequence of EUV images of the solar corona. An optical flow technique is used to estimate the apparent displacement of the coronal features between s uccessive frames. The final goal is the systematic search of outstanding coronal events. In particular we will focus on the CME signatures such as loop opening. This motion analysis algorithm is able to track and analyze the displacements of various coron al objects, with a simultaneous assessment of intensity variations associated to these structures. The possibility of application to the whole EIT database will be demonstrated. Its extension to data from future solar imagers (SWAP, STEREO/SECCHI), depend ing on instrument parameters, will also be discussed.

## Coronal magnetic field reconstruction by vectortomographic methods

KRAMAR, M., INHESTER, B.

#### **Abstract**

Since the magnetic field dominates the equilibrium of the corona a good guess of the coronal magnetic field may be vital for the 3D reconstruction of coronal structures. We investigate the possibility to reconstruct the coronal magnetic field not only from photospheric measurements but from polarization images of magnetically sensitive coronal lines. As these observations are line-of-sight integrals, the magnetic field reconstruction problem can in principle be solved by methods similar to those applied in tomography.



#### Automated Coronal Loop Identification using Digital Image Processing Techniques II

LEE, J.K., GARY, G.A., NEWMAN, T.S.

#### Abstract

Ongoing studies of computer algorithms for the automatic identification/detection of optically-thin, 3-dimensional solar coronal loop structures from 2-dimensional TRACE satellite image will be discussed. Detection of coronal loop structures is a challenging solar image processing problem due to the blurry boundaries and complex shapes of the coronal loop structures. In addition, coronal loops have low contrast segments and the photon and detector noise are present in the image. The automated detection of coronal loop structures will help the rapid analysis of dynamic solar activities. The detected loops (i.e., the derived magnetic field lines) can provide a boundary condition for the reconstruction of the solar magnetic field. To identify the coronal loops, our first automated coronal loop identification technique (Oriented Connectivity Method, Lee et al., Intl Conf. of Pattern Recognition, 2004) exploited the physical constraint of the solar magnetic field on the coronal loop structures. In this presentation, we will introduce a second automated coronal loop identification technique that exploits the local intensity distribution of the coronal loop structures. The technique is a dynamic aperture-based method which segments the loop pixels by the dynamic movement of the aperture on the potential coronal loop structures. Several image preprocessing and post-processing steps and the experimental results on the synthetic and real coronal image will also be presented. This work was supported by NASA's Office of Space Science - Solar and Heliospheric Physics Supporting Research and Technology Program.

## Study of coronal loops from GOES-SXI images

LOPEZ-FUENTES, M.C., MANDRINI, C.H., KLIMCHUK, J.A.

## **Abstract**

We study the evolution of coronal loops observed by GOES-SXI. Although this instrument has a coarser spatial resolution than TRACE or SXT, it has the advantage of continuous temporal coverage. Then, we are able to obtain light curves of loops for longer periods than in previous works based on SXT observations (see e.g., Porter and Klimchuk 1995, ApJ, 454, 499). Applying the filter ratio technique using images observed in different instrument passbands we infer the temperature and emission measure of observed loops. We compute the timescales of the radiative and conductive cooling and we find that they are typically 1 order of magnitude shorter than the evolutionary timescales. We show that this situation can be alternatively explained by steady heating or impulsive heating by nanoflares. We compare the studied SXI loops with loops observed by TRACE and SXT and we discuss the implications in terms of both possible heating scenarios.

This work is funded by NASA and the Office of Naval Research.

## Determination of the Amount of Clustering used by an Adaptive Regularization Algorithm in the Restoration of Solar Radio Images

MACHADO, W.R.S., MASCARENHAS, N.D.A., COSTA, J.E.R.

## **Abstract**

The proposed technique is based on the use of adaptive regularization procedures that incorporate the k-means clustering algorithm over local roughness measures. A test verified that the performance of the algorithm depends mainly on the regularization parameter of the deconvolution procedure. The use of the proposed adaptive regularization algorithm based on clustering can generate better results than those obtained by the conventional regularization filter.

# **High-Performance Data Analysis**

MESSMER, P.

## **Abstract**

The Interactive Data Language (RSI/IDL) is a standard tool used by many researchers in observational fields. While its capabilities are sufficient for data analysis of most present day missions, the amount of data produced by upcoming missions and the increasing complexity of image processing algorithms requires higher computing power.

Cluster computing is a cost-effective way to increase the speed of computation, but algorithms have to be modified to take advantage of parallel systems. Enhancing IDL to work on clusters gives scientists access to increased performance in a familiar programming environment.

We will demonstrate that by using FastDL, an IDL wrapper for the message passing interface (MPI), significant speedup can be achieved for running IDL scripts on a cluster. We will also discuss methods to simplify the parallelization of IDL scripts.

# Reconstruction of waiting time distribution from SIDC flares catalog

PODLADCHIKOVA, E., VAN DER LINDEN, R., LEFEBVRE, B., Krasnoselskikh, V.

#### **Abstract**

We compute flares waiting time distribution using Parzen-Rosenblatt method and two years of data from a flare catalog that was built at the Solar Influences Data analysis Center (SIDC) of the Royal Observatory of Belgium based on the SEC/NOAA daily events lists. This catalog includes smaller flares than the 'solarsoft' one used in a previous study [Lepreti et al. 2001, 2003]. For the solarsoft list, we have found power-law or exponential distributions, depending on the definition of waiting times, in qualitative and quantative agreement with Wheatland et al. 1998; Lepreti et al. 2001, 2003, Buchlin et al, 2004. However for SIDC database, the type of distribution is much less sensitive on waiting times definition. PDFs have heavy tails with an approximately power-law decay, but characteristic times are present also. We compare these distributions with the waiting time distributions from a lattice coronal heating model with the differents scales of magnetic driving and using different type of current sheet dissipation [Krasnoselskikh et al. 2002, Podladchikova et al. ]

# **Automatic Solar Flare Tracking Using Image Processing Techniques**

Qu, M., Shih, F.Y, Jing, J., Wang, H.

#### **Abstract**

Measurement of the evolution properties of solar flares through their complete cyclic development is crucial in the studies of Solar Physics. From the analysis of solar  ${\rm H}\alpha$  images, we used Support Vector Machines (SVMs) to automatically detect flares and applied image segmentation techniques to compute their properties. We also present a solution for automatically tracking the apparent separation motion of two-ribbon flares and measuring their moving direction and speed in the magnetic fields. From these measurements, with certain assumptions, we inferred the reconnection of the electric field as a measure of the rate of the magnetic reconnection in the corona. The automatic procedure is a valuable tool for real-time monitoring of flare evolution.

## Fractal techniques in the analysis of solar images

REVATHY, K., PRABHAKARAN NAYAR, S.R.

## **Abstract**

Fractal concepts are used to describe the dynamic properties of irregular structures. The computation of local fractal dimension followed by segmentation technique has proved to be an efficient method in extracting regions of interest from an image. We have computed local fractal dimension using different approaches like Sarkar's method and variation method. This is followed by different segmentation methods like iterative thresholding, region growing and histogram based thresholding applied to fractal dimension values. The performance of these methods are discussed. We propose a modified variation method to compute the fractal dimension and its application in the analysis of SOHO images. Using this method, the active regions and their evolution could be elegantly detected. The area of the active region detected using this algorithm is found to be highly correlated with the spectral flatness measure of the image.

# First light from prototype of Brazilian Decimetric Array

SAWANT, H.S., AND THE BDA TEAM

#### **Abstract**

The Prototype of Brazilian Decimetric Array (PBDA), consisting of 5 elements of 4 meter diameter mesh type parabolic antennas altaz mounted, unique in Latin America, has been successfully developed. This array operates in the frequency range of (1.2-1.7) GHz and it is presently located at the campus of the Brazilian National Space Research Institute (INPE), at So Jos dos Campos, Brazil. Each element is separated by 8 meter, thus having base line of 32 meter. Operating frequency is 1.5 GHz. Each pair of antenna was initially tested in analogical mode by observing sun. The first light from this array was recorded on 8th February, 2003 in the analogue mode. Later on the digital correlator was interfaced with this array and ten base lines were tested for their fringe rates. Expected and observed fringe rates are almost within the limits. Fringes are recorded for four hours by tracking sun. A weak solar flare has been recorded on 22nd March, 2003 (14:00 UT), in 1.5 G Hz, using 2 elements of PBDA. These observations will be presented. Since July 2004, the array have been shifted to INPEs campus at Cachoeira Paulista, where the baselines have been increased to 300 x 180 meters, so as to have solar maps with resolution of 3 x 4 arcminutes. The datails and the status of the project will be presented.

## Dimension wavelet cartography of the solar surface

SYCH, R.A., SAWANT, H.S., ROSA, R.R.

### **Abstract**

A research project on the study and practical implementation of the Waveletanalysis method for obtaining spectral characteristics of time series of 2-dimensional solar images is presented. Within the context of investigating the oscillatory processes of coronal loops, a spatial-analysis technique for two-dimensional images of EUV emission sources (TRACE, 171 A) is suggested. It is based on identifying two-dimensional sources of quasi-periodic fluctuations, both within the frequency band and at separate harmonics. The use of direct and inverse Wavelet transform as the frequency band filter for each spatial point forms a groundwork for identification. It enables determination (in time and in space) the areas of the image which make the main contribution to the emission at selected frequencies. Dynamic and phase characteristics of two-dimensional variations of sources are obtained. It is shown that the principal source of the variations at high frequencies lies at the loop footpoints. The low-frequency component is basically concentrated within thin tubes delineating magnetic field lines. These magnetic lines are internal structures of the loops. Emission surges of solar material along the loops were observed to occur at some of the harmonics.

# Using Feature Tracking to Quantify Flux Cancellation Rates

WELSCH, B.

### **Abstract**

Cancellation of photospheric flux might play an essential role in both the formation and eruption of prominences. Using a feature tracking code applied to magnetograms, we are attempting to automate the determination of flux cancellation rates. I plan to address the following questions: 1) What are "features" in magnetograms, and how are they tracked? 2) How do we define cancellation of these features? 3) How should features evolve as they cancel? And, finally, the most difficult question: 4) What have feature tracking results told us about cancellation?

# How to use magnetic field information for coronal loop identification

WIEGELMANN, T., INHESTER, B.

#### Abstract

The structure of the solar corona is dominated by the magnetic field because the magnetic pressure is about four orders of magnitude higher than the plasma pressure. Due to the high conductivity the emitting coronal plasma (visible e.g. in SOHO/EIT) outlines the magnetic field lines. The gradient of the emitting plasma structures is significantly lower parallel to the magnetic field lines than in the perpendicular direction. Consequently information regarding the coronal magnetic field are useful for the interpretation of coronal plasma structures. We extrapolate the coronal magnetic field from photospheric magnetic field measurements into the corona. The extrapolation method depends on assumptions regarding coronal currents, e.g. potential fields (current free) or force-free fields (current parallel to magnetic field). As a next step we project the reconstructed 3D magnetic field lines on an EIT-image and compare with the emitting plasma structures. Coronal loops are identified as closed magnetic field lines with a high emissivity in EIT and a small gradient of the emissivity along the magnetic field.

# An Automatic System for CME Detection and Source Region Identification

ZHANG, J., POLAND, A., WECHSLER, H., BORNE, K.

#### Abstract

The detection, tracking and characterization of CMEs is an important task for the Sun-Earth Connection study and space weather prediction. As the amount of data available and expected for such analysis is overwhelming there is an urgent need to automate this process. We identify three tasks that are crucial to this process: (1) CME detection, tracking and characterization, (2) Detection of coronal dimmings, and (3) Location of CME source regions by associating CMEs with coronal dimmings. Towards that end we plan to develop automated computational means driven by image processing, computer vision, machine learning, pattern recognition, and data mining methods. The main modules for our automated system include: (A) preprocessing to improve the quality of data using morphology and relaxation tools, (B) detection of CMEs and coronal dimmings using a combination of methods including boundary detection, region growing and wavelet analysis, (C) tracking CMEs using Condensation (Conditional Density Propagation) methods, (D) characterization of CMEs in terms of position, height, size, speed and mass versus time, and (E) spatial/temporal data mining of associations between CMEs and coronal dimmings. The system is iterative and the steps ("modules") reinforce each other in their findings. We will develop the software tools needed and test the system using the CME observations from LASCO (Large Angle Spectrometer and Coronagraph) and coronal observations of EIT (Extreme-ultraviolet Imaging Telescope) from the SOHO spacecraft.